EUROPEAN COMMISSION

JOINT RESEARCH CENTRE

Institute for the Protection and Security of the Citizen

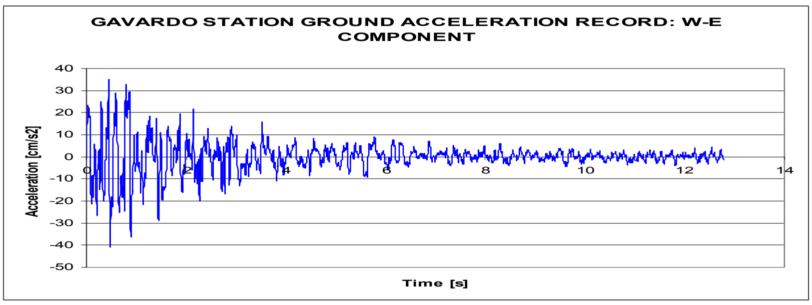
European Laboratory for Structural Assessment (ELSA)

I-21020 Ispra (VA), Italy

The Garda Area (Italy) Earthquake of 24 November 2004: A Field Report

S. Dimova, E. Mola, P. Negro, A.V. Pinto

A. Colombo (University of Trento)



2004

EUR 21513 EN

A great deal of additional information on the
European Union is available on the Internet.
It can be accessed through the Europa server
(http://europa.eu.int)

EUR 21513 EN

Printed in Italy

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

Silvia Dimova is a JRC Seconded National Expert from the Central Laboratory for Seismic Mechanics and Earthquake Engineering, Bulgarian Academy of Sciences, Letter No.B01-HR/BLI/emo/D(2004)6565.
Elena Mola is a JRC Research Fellow, contract N. 18786-2001-11 P1B20 ISP IT.

The support of the European Commission is acknowledged.

During the field mission contacts were taken with the Mayor of Vobarno, who was so kind as to personally give the ELSA team a picture of the damage distribution in his village and the relevant statistics for Vobarno. Moreover, he granted our team access to the fraction of Pompegnino, which had suffered the most significant damage.
In Pompegnino, contacts were taken with Mr. Cadenelli from the local C.O.A., who led the team on a guided tour of the village to gather the photographic documentation.
The kindness and patience of both are therefore gratefully acknowledged.

During the visit to the Salò C.O.M. contacts were taken with volunteers from Regione Lombardia, who were very helpful in providing us with the general statistics of the safety assessment interventions for the area.

Moreover, contacts were taken with Professor Riva from the University of Brescia. The kindness of Professor Riva in sharing with us all the relevant information on and contacts is gratefully acknowledged.

Silvia Dimova wishes to thank Professor Rumiana Glavhceva, Head of Seismological Department of the Geophysical Institute at the Bulgarian Academy of Sciences, whose expert review and helpful remarks were invaluable to improve our description of the intensity of damage.

The Authors wish to thank Dott. Paolo Marsan, Head of the Accelerogrammetric Network of Protezione Civile, for providing us with the digitalized records of the Gavarno station: his kindness and promptness in fulfilling our request are gratef7ully acknowledged.

ABSTRACT

On November 24 2004 an earthquake hit the area of Garda Lake, part of the Lombardia region in Italy. The magnitude of the event was estimated in 5.2 on the Richter scale and, at a local level, its effects were remarkable, especially in some municipalities where an intensity of VII-VIII on the MCS scale was reached.

The importance of the event, the vicinity of the area, the need to investigate the performance of buildings and structures to the earthquake called for a field mission by the ELSA Earthquake Engineering Staff. The mission consisted of a full-day trip to the area, on December 1 2004, one week after the event, when the effects of the earthquake and its consequences on the environment and the people were still evident.

This report presents the evidence collected in the trip by means of a complete photographic documentation. Moreover, an introduction regarding the historical seismicity of the region and an estimation of the main features of the earthquake is provided. Finally, the behaviour of different categories of buildings, from masonry ones to reinforced concrete, to historical ones, is analysed and discussed and an overview of the procedures used to deal with the emergency is carried out.

1 INTRODUCTION

On November 24 2004 an earthquake hit the area of the Brescia province around Lake Garda in Lombardia, Italy. Though the magnitude of the event was 5.2 on the Richter scale, the effects it caused on some of the building stock of the area were remarkable, given the many historical private and public buildings present in the area and the very large majority of stone and brick masonry structures in the private housing building stock.

The relevance of the event, the vicinity of the area and the need to investigate the performance of buildings and structures to the earthquake called for a field mission by the ELSA Laboratory Earthquake Engineering Staff. The mission consisted of one full-day trip around the epicentral area and took place on December 1 2004, one week after the event, when the effects of the earthquake and its consequences on the environment and the people were still evident.

The aim of the present field report is to carry out a thorough overview of the most significant aspects of the event, referring to the evidence collected during the field trip, to the documentation collected in preparation for the mission and to the information gathered through exchanges with experts and locals met on the field.

In Chapter 2 the seismological framework of the event is traced, referring to the historical seismicity of the area and to its tectonic configuration; a description of the event is then carried out. In Chapter 3 a description of the damage distribution, with the observed microseismic intensities, is given. In Chapter 4, a detailed description of the damage reported by the different categories of structures present in the area is performed; masonry buildings, reinforced concrete buildings, historical churches are considered; a photographic documentation gives a vivid representation of the effects of the earthquake. Chapter 5 is devoted to the procedures for dealing with the emergency situation caused by the earthquakes, in particular data on the homeless, the inspected structures and the other relevant statistics that could be collected at the time of the visit. Finally, in Chapter 6, the conclusions drawn from the field trip and the survey performed about the event are presented.

2 SEISMOLOGY AND GEOLOGICAL ASPECTS

2.1 Geology and tectonics

The Mediterranean basin area has a quite complex tectonic configuration. In this relatively small area, in fact, different kinds of seismogenetic zones can be found. Some of them are characterized by compressive tectonic movements leading to subduction (the Alps or the Hellenic Arch), some others are characterized by elongation and sliding ([1], [2]).

The seismic activity in the Italian Peninsula is mainly caused by the converging movements of the African and the Eurasiatic plates. This causes high seismicity in Italy, both from the frequency and from the intensity point of view. The events taking place in Italy are possibly correlated with those happening on the Eastern coasts of the Adriatic Sea.

The Apennine area shows a mostly diverging tectonic activity, with some areas characterized by compressive stresses, on the eastern side. This shows a complex activity that is possibly due to the rotation of the Atlantic micro-plate, added to marked disomogeneity at crustal level. For this reason, the seismicity in Italy is quite high, as can be observed in Figure 2.1, where a map of the events with M ≤ 4 in the Mediterranean area is represented. In Italy such events are present everywhere.

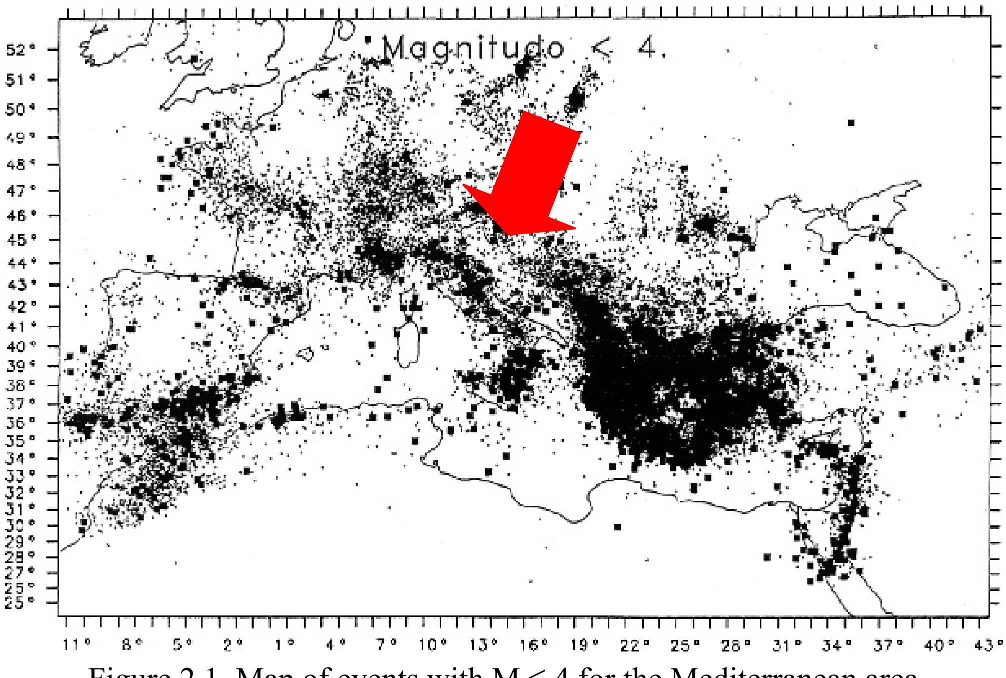


Figure 2.1. Map of events with M ≤ 4 for the Mediterranean area

From Figure 2.2, showing a map of events with M > 4, it can be seen that also stronger earthquakes are quite common, especially in certain areas (in the map the squares represent events with 5 ≤ M ≤ 6 and the circles represent events with M<5). In particular, the most critical areas are in the Apennine mountains, where in the last 30 years the major events took place; many of them have M > 5, reaching 6 for the Irpinia earthquake of 1980.

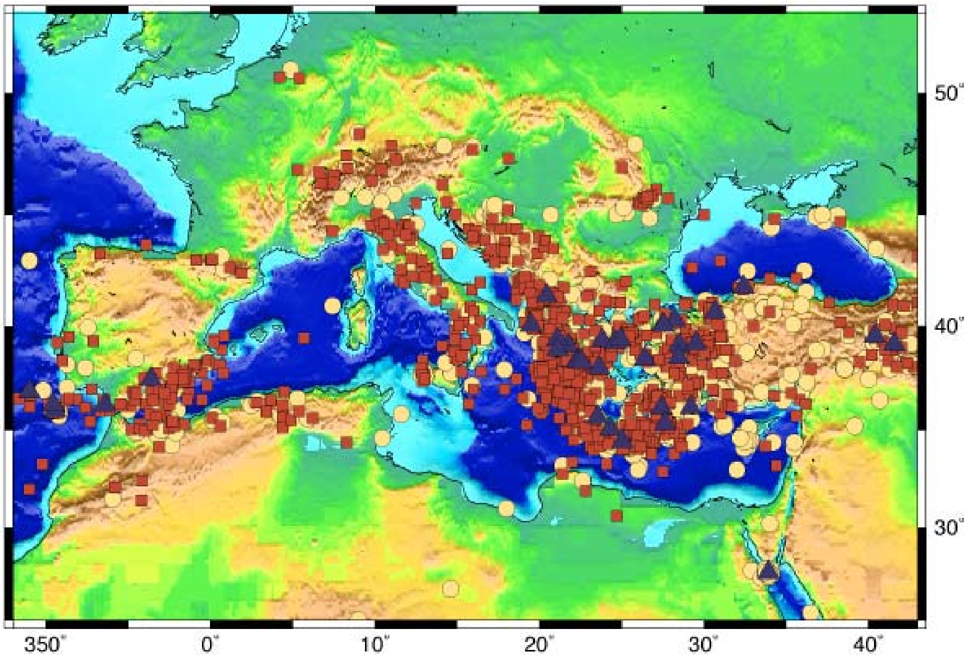


Figure 2.2. Map of the events with M>4 for the Mediterranean area

2.2 Historic seismicity

The historic seismicity of the area of Garda Lake is well known. The most relevant event that took place in the area was the earthquake of 30 October 1901. On that day a very strong earthquake hit a number of municipalities in the province of Brescia, part of the Lombardia region in Italy.

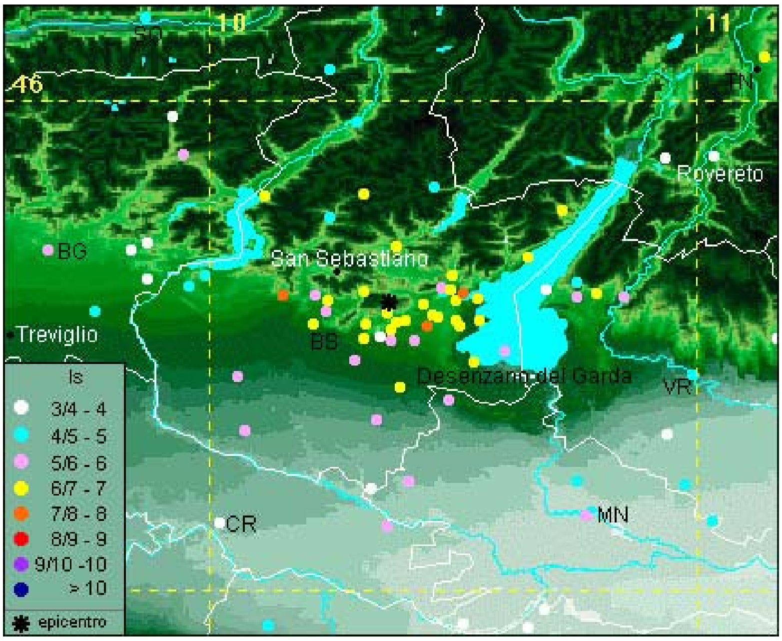


Figure 2.3. Map from the “Parametric Catalogue of Italian Earthquakes”, from [3]

In Salò, a small town on the Garda Lake, and one of the areas damaged by the recent earthquake, the intensity of that event reached VIII on the Mercalli Scale. On that occasion, diffused cracking to the housing building stock was observed, together with a number of failures; landslides and movements were also reported. In Fig. 2.3 the representation of that earthquake in the Italian Catalogue of Seismic Events is reported (from [3]). In [4], the peculiarity of the seismic area of Lake Garda is described as being the conjunction ring between the Lombardia and Veneto areas, delimited on one side by the river Adige and on the other by the river Chiese. A description of the historic seismicity of the area is also given: municipalities such as Salò, Malcesine and Cassone are reported to have suffered many a strong and localized earthquakes. Among the most relevant events, the earthquake of 5 January 1892 is cited: it was reportedly most intense in Salò and Vobarno, two of the municipalities that were also involved in the latest event. The region being delimited by two seismic epicentral areas located on the two opposite sides of the Garda Lake, it has historically resented of the activity of both: when, on the Veneto side (in the province of Verona), periods of intense seismicity came along, on the opposite side (in the province of Brescia) events were often registered at the same times too.

2.3 Description of the earthquake of 24 November 2004

On 24 November 2004, at 23:59 local time (22:59 GMT), a seismic event of magnitude 5.2 on the Ricther scale hit the area of the province of Brescia (Lombardia, Italy) around Lake Garda. The main event was followed by a series of minor quakes, of very small magnitude, ranging between 1.7 and 2.1, not felt by the population but recorded by the Italian accelerogram net and reported on the National Institute of Geophisics and Vulcanology (INGV) website [5].

TIME	DATE	MAGNITUDE
00:48	25/11/2004	Magnitude: 1.7
00:49	25/11/2004	Magnitude: less than 1.7
00:53	25/11/2004	Magnitude: 1.7
00:55	25/11/2004	Magnitude: 1.7
02:25	25/11/2004	Magnitude: 2.1
05:22	25/11/2004	Magnitude: 2.0

Table 2.1. Minor aftershocks (from the INGV website, [5])

The location of the epicentre of the main event can be observed in Fig. 2.4. Acording to the preliminary report by INGV, the main municipalities located at less than 3 km from the epicentre are: Vobarno and Gardone Riviera; in a 6 km radius area from the epicentre are the towns of Salò, Sabbio Chiese and Toscolano Maderno. In Fig. 2.5, a more detailed map of the area is represented; the relative positions of the small villages of Vobarno, Gardone Riviera and Toscolano Maderno can be observed. This map was located in the C.O.M. (Centro Operativo Misto) of Salò, the emergency management unit set up immediately after the event and still operative at the time of the field mission (for further information and a more detailed description of the emergency management procedures see Chapter 5).

According to the new Seismic Classification of Italy, referred to the Nuova Ordinanza PCM of 20 March 2003 [6], the epicentral area is in seismic category 2: as can be seen in the map represented in Fig. 2.6, from [7], this means that the horizontal ground acceleration value with a probability of exceedance of 10% in ten years is in the range 0.15-0.25g. For the same category, the 0-period horizontal acceleration given is 0.25g.

The estimated depth of the event was of about 8 km: due to the superficial location of the epicentre, the earthquake was felt over a very large area of Italy, from region Lombardia to Veneto, Piemonte (located in North-East and North-West Italy, respectively), to Toscana and Emilia-Romagna (located in the centre of the Italian peninsula), to Switzerland, Austria and Slovenia.

Preliminary moment-tensor solutions for this earthquake carried out by the United States Geological Survey, [8], imply that the shock occurred as the result of movement on an inverted fault, as represented in Fig. 2.7. In the picture, the 'beach ball' representation of the source mechanism for the earthquake is given, together with the slip, dip and strike data that locate and describe it exactly. This solution was performed by INGV-Harvard European-Mediterranean Regional Centroid-Moment Tensors Project.

The tectonics of the area is represented in Fig. 2.8: the main active tectonic structures are reported, together with the epicentres of some historic earthquakes. The event under study was part of the activity of the Giudicarie fault system.

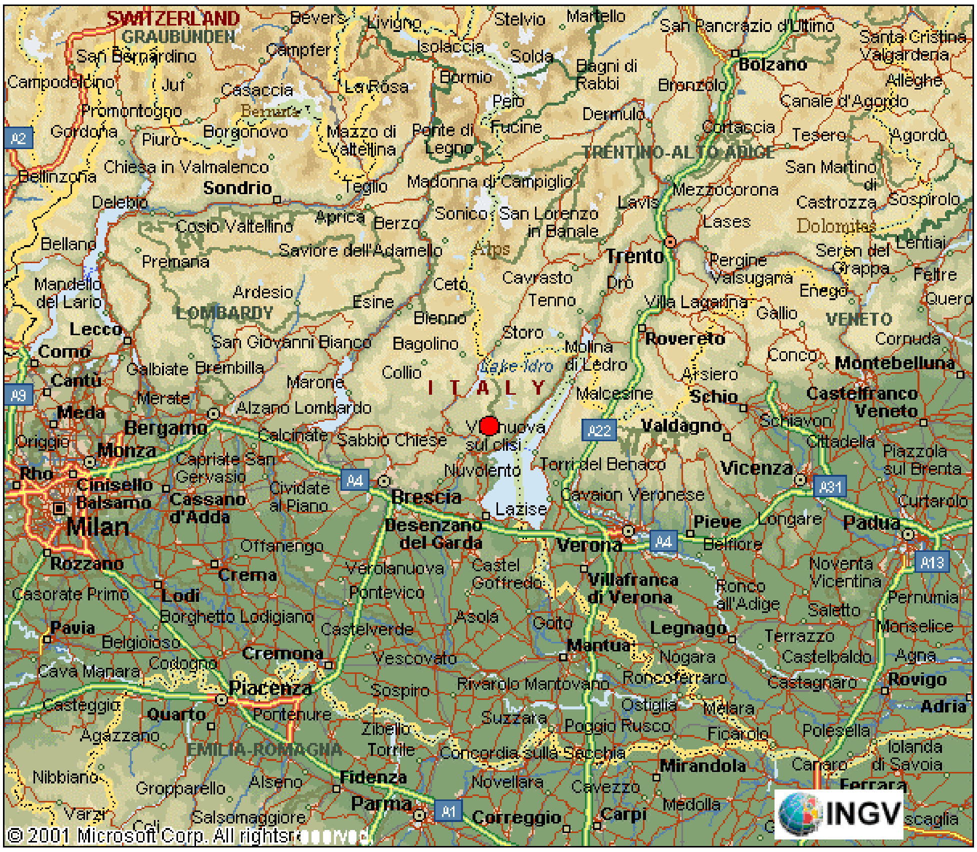


Figure 2.4. Epicentre of the earthquake

In Fig. 2.9, the epicentre of the 24 November earthquake and its focal mechanism are compared to the cinematic sources of the seismogenetic system which caused the 1901 earthquake (the source is the new version, yet to be published, of the *Database of potential Sources for Earthquakes larger than M 5.5 in Italy*, 2001). It can be seen that the recent earthquake is well framed in the activity of the Giudicarie System: both the type of mechanism (inverted fault) and its direction (strike) are in good agreement with this conclusion.

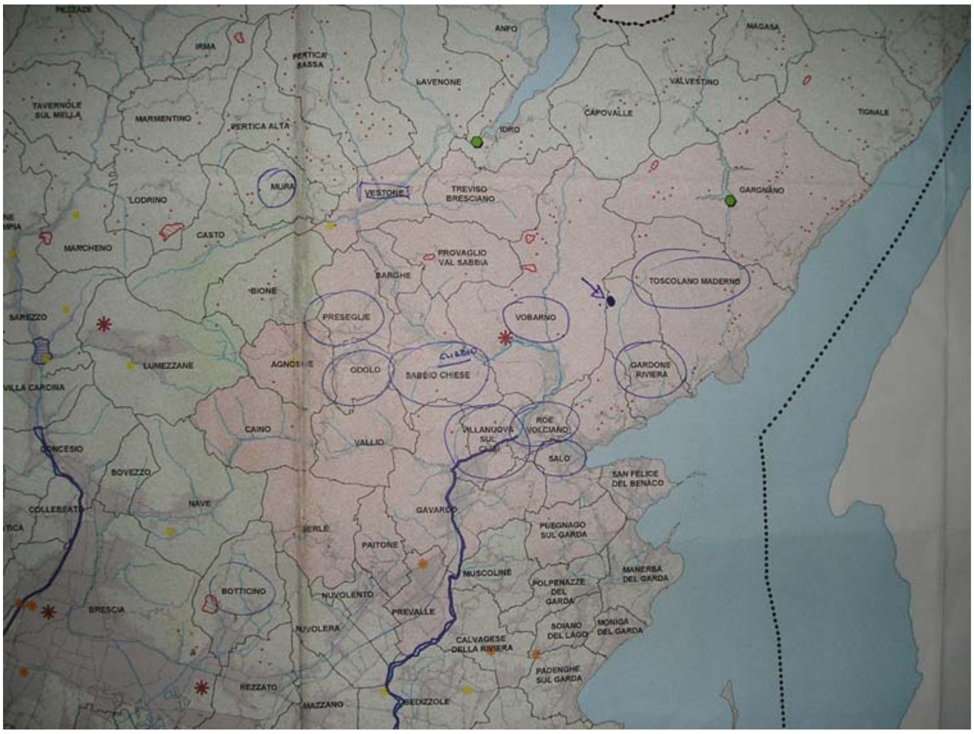


Figure 2.5. Map of the epicentral area (from the C.O.M. in Salò)

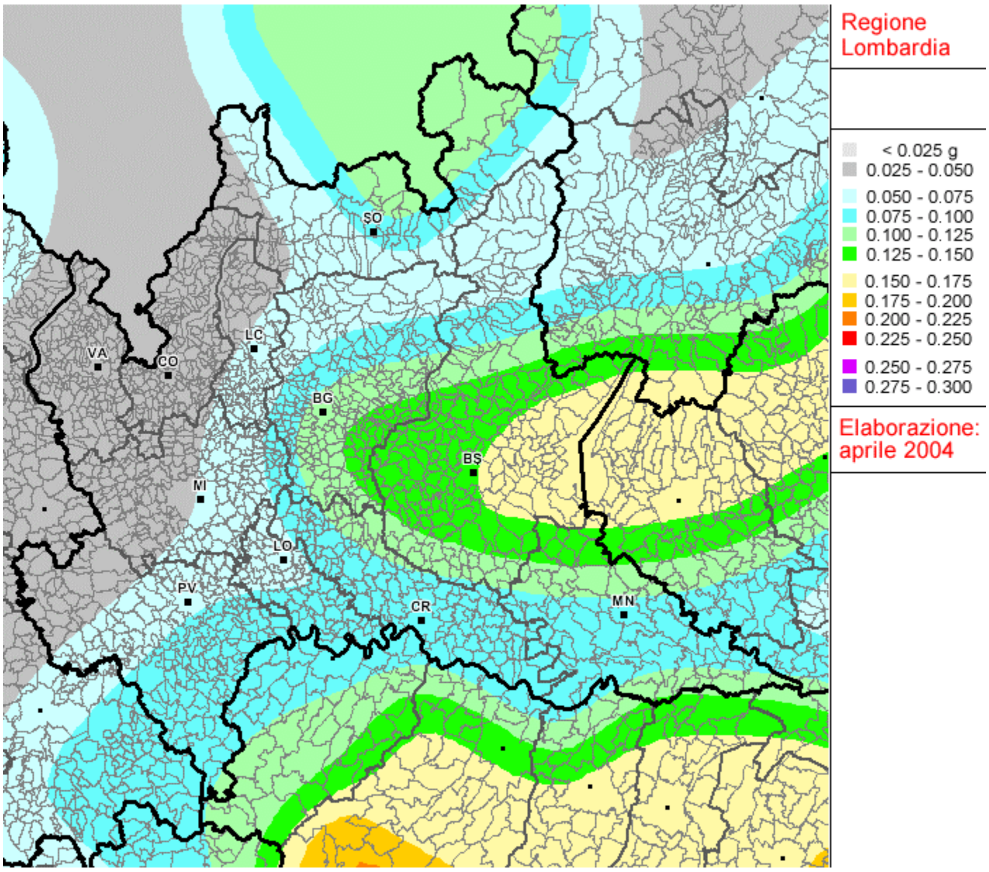


Fig. 2.6 Seismic Classification Map for Lombardia (from [7])

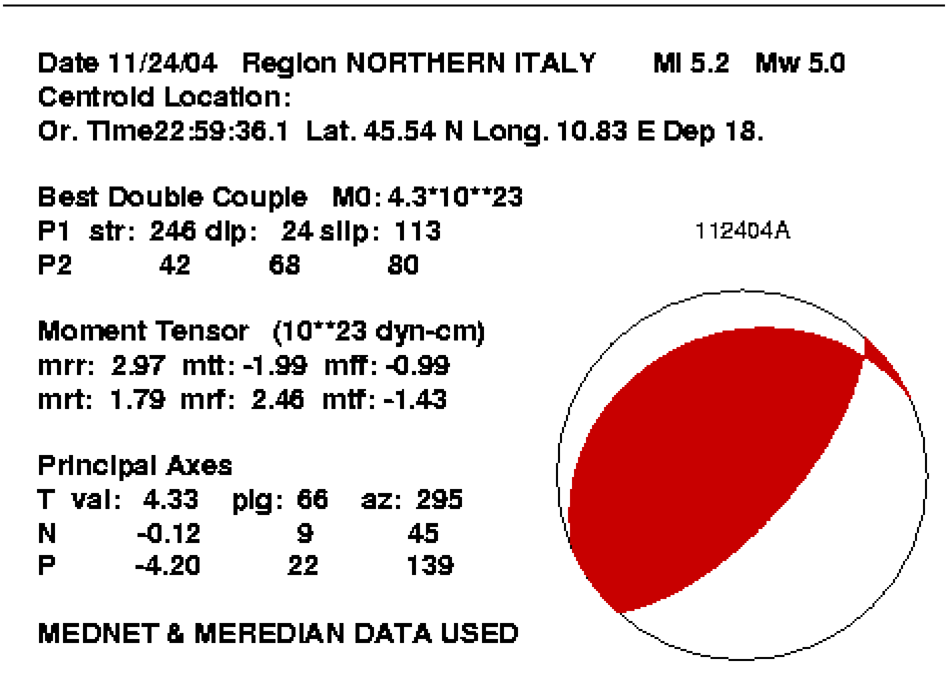


Figure 2.7 Moment tensor solution for the main shock

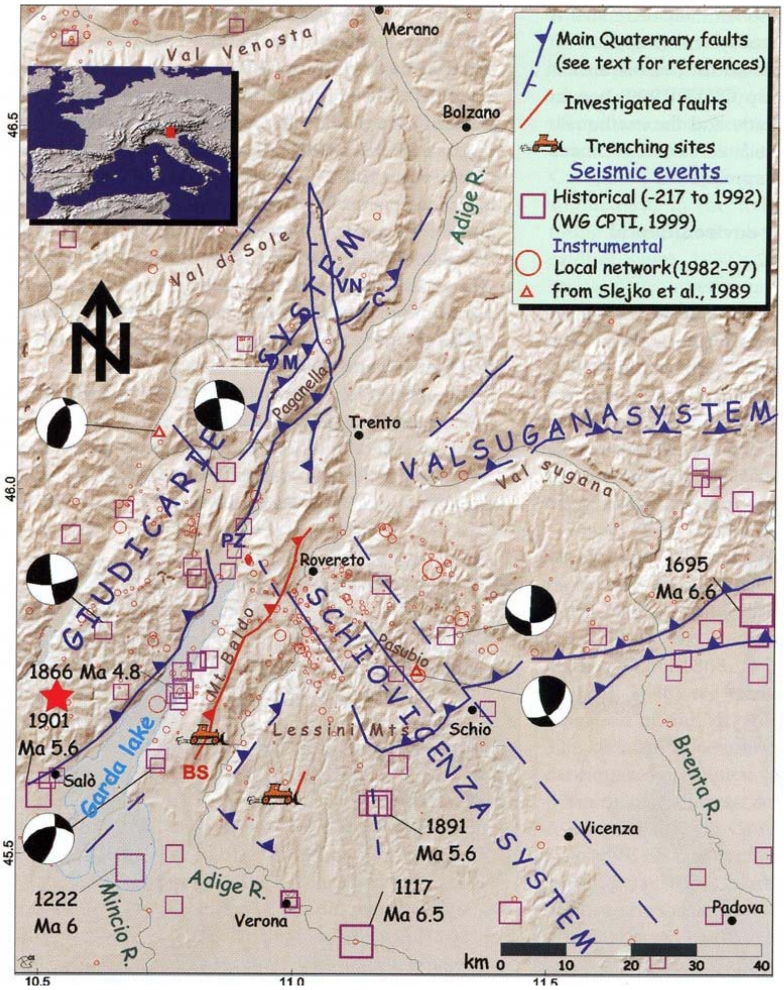


Figure 2.8. Tectonics of the Lake Garda area

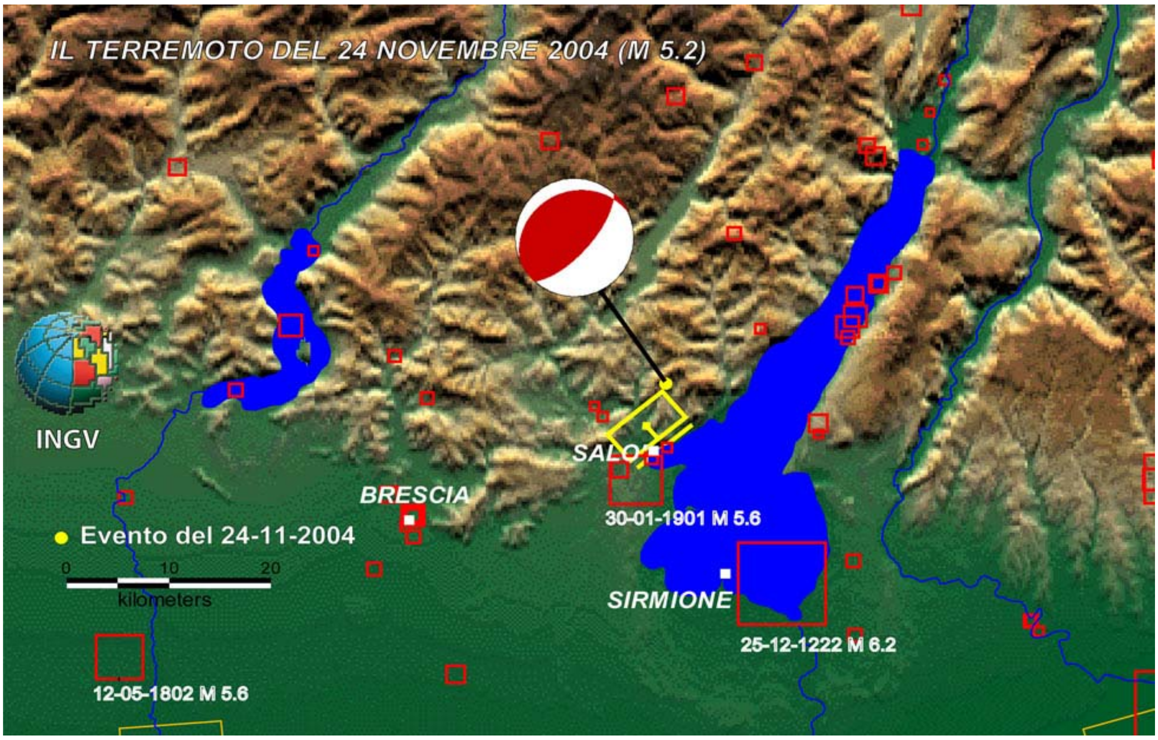


Figure 2.9. Historical earthquakes, 2002 events and tectonic configuration of the area

2.4 Strong motion records

As reported in [9], following the main event of 24 November the Italian RAN Network (National Accelerometric Network) station of Gavardo, located at less than 10 km from the epicentre, was activated.

Fig. 2.10. Location of the accelerometric stations in the epicentral area (from [9])

The recorded peak ground acceleration (PGA) was around 0.077g (about 76 cm/s^2) on the longitudinal component (NS direction). Gavardo is an analogic measurement station; no digital stations are located near the epicentral area. In the following the digitalized signals obtained from the analogic measurements are reported. The only digital station that recorded a signal is located in the Gran Sasso area, in the Abruzzo region, at more than 500 km from the epicentre. In the latter station the recorded PGA was of 0.023 cm/s^2.
Starting from the afternoon of 25 November, three temporary digital stations were set up in the area: one of them was located at the Salò C.O.M. (Centro Operativo Misto, described in detail in Chapter 5); the other two stations were located in Toscolano Maderno, one of them on rock soil, the other on soft soil to point out any possible site effects. Of the three aftershocks with magnitude ≥ 2.5 reported by INGV, two were also recorded by the temporary digital stations.
In Fig. 2.10 the map with the location of the temporary station is represented. Tab. 2.2 gives the PGA values and the magnitudes of the main event, as registered in the two RAN stations of Gavardo and Gran Sasso stations.

Tab. 2.2. Recorded data from RAN and temporary accelerometric stations (from [9])

Station	A/D	Place	Time	Direct.	PGA(cm/s^2)	Magnitude
GVD	A	Gavardo (Gazzino)	24/11/04 22:59	Long.	158.76	5.2
GVD	A	Gavardo (Gazzino)	24/11/04 22:59	Vert.	91.14	5.2
GVD	A	Gavardo (Gazzino)	24/11/04 22:59	Trasv.	99.96	5.2
GSG	D	Gran Sasso	24/11/04 22:59	XTE	-0.021	5.2
GSG	D	Gran Sasso	24/11/04 22:59	YLN.	0.023	5.2
GSG	D	Gran Sasso	24/11/04 22:59	ZUP	-0.022	5.2
SAS (SAL)	D	Salò C.O.M.	26/11/04 05:39	XTE	1.618	2.7
SAS (SAL)	D	Salò C.O.M.	26/11/04 05:39	YLN.	1.943	2.7
SAS (SAL)	D	Salò C.O.M.	26/11/04 05:39	ZUP	-6.277	2.7
GAI	D	Gaino (bunker)	27/11/04 08:45	XTE	2.751	2.5
GAI	D	Gaino (bunker)	27/11/04 08:45	YLN.	-2.507	2.5
GAI	D	Gaino (bunker)	27/11/04 08:45	ZUP	2.018	2.5

In Fig. 2.11 the digitalized ground acceleration recorded by the analogic instrumentation in the Gavardo station (provided courtesy of the Protezione Civile) is reported. The two horizontal and the vertical component are represented.

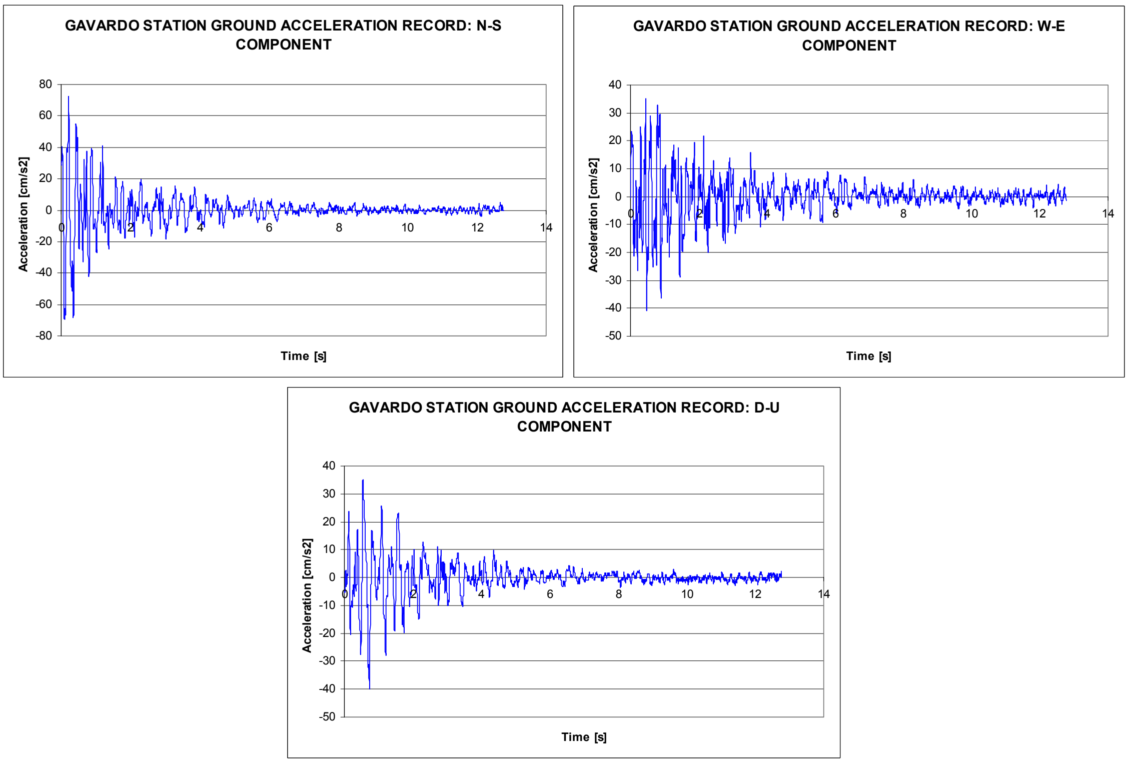


Fig.2.11 The Gavardo station records of the main shock (NS, WE and vertical components)

In Fig. 2.12, the elastic spectrum computed for the main shock recorded signal in Gavardo is represented. The peak value of the spectral acceleration is rather small and the spectrum exhibits a band concentration of high values for high frequencies

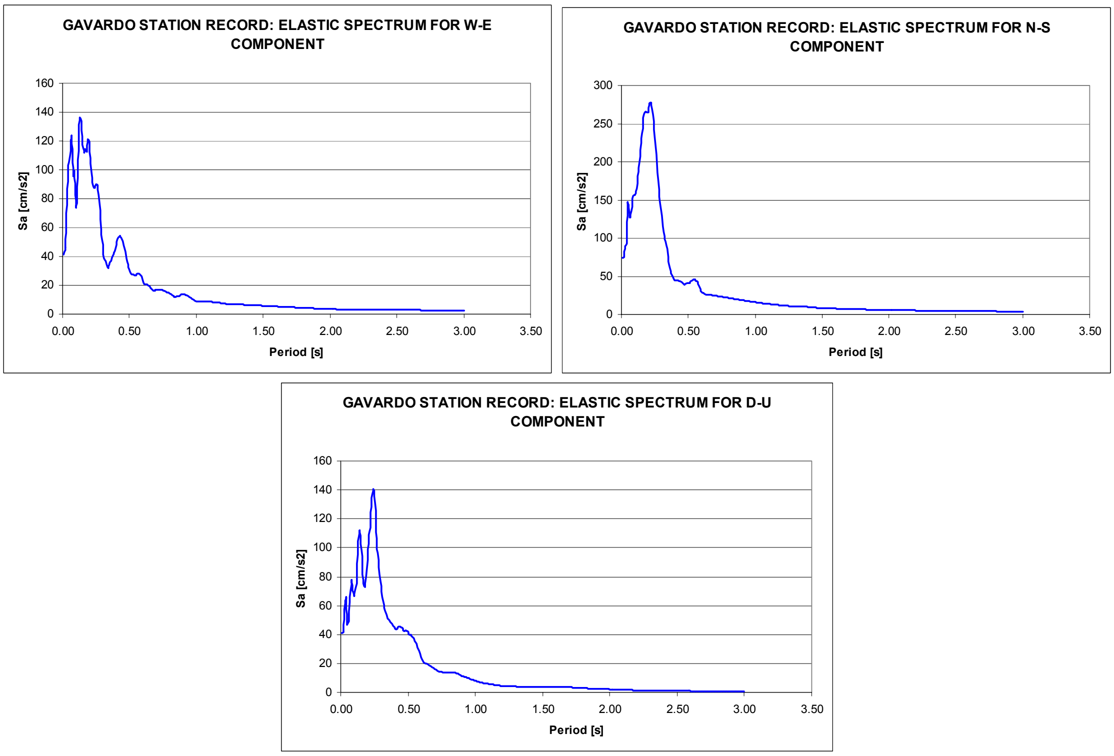


Fig.2.12 Elastic spectrum for the Gavardo station record of the main shock

Finally, in Fig. 2.13 a), the inelastic spectra computed for the main component of the main shock are reported. The corresponding ductility demand is almost negligible, except for high frequencies.

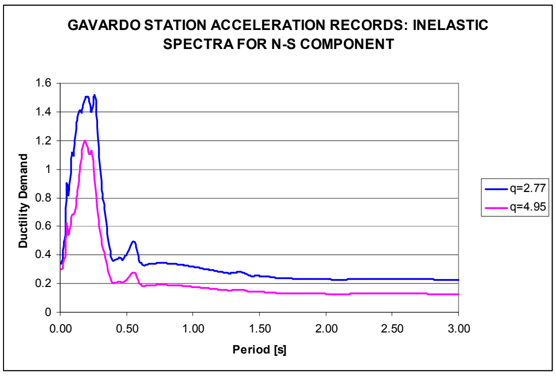


Fig.2.13 Inelastic spectra for the main component (N-S) of the Gavardo station record of the main shock

2.5 References

1 D. Molin, M. Stucchi & G. Valensise. *Massime intensità macroseismiche osservate nei comuni italiani*, http://emidius.mi.ingv.it/GNDT/IMAX/imax.html, Dipartimento della Protezione Civile; 1996

2 D. Slejko, R. Camassi, I. Cecic, D. Herak, M. Herak, S. Kociu, V. Kouskouna, J. Lapajne, K. Makropoulos, C. Meletti, B. Muco, C. Papaioannou, L. Peruzza, A. Rebez, P. Scandone, E. Sulstarova, N. Voulgaris, M. Zivcic & P. Zupancic. *GSHAP seismic hazard assessment for the Adria region*, http://seismo.ethz.ch/gshap/adria/, Global Seismic Hazard Assessment Program; 1999

3 INGV: Istituto Nazionale di geofisica e Vulcanologia, http://www.ingv.it

4 M. Baratta, *I Terremoti d'Italia*, Arnaldo Forni Editore; 1900

5 INGV: http://www.ingv.it/terremoti/bresciano2004/bresciano.html

6 Ordinanza PCM del 20 Marzo 2003, N.3274

7 http://zonesismiche.mi.ingv.it/mappa_ps_apr04/italia.html

8 USGS: http://earthquake.usgs.gov/recenteqs/, Earthquake Hazards Programme, United States Geological Survey; 2002.

9 Protezione Civile: http://www.protezionecivile.it/cms/attach/rapporto_garda.pdf

3 DAMAGE DISTRIBUTION: OBSERVED MICROSEISMIC INTENSITY

3.1 Vulnerability class according to the European macroseismic scale

The observation of the affected area has shown that the structural damage is concentrated in the historical centers of the villages. There, the prevailing part of the building stock consisted of two (rarely three) storey non-engineered masonry houses. Having in mind that a considerable part of these structures during its 200-300 years long exploitation has been subjected to many non-engineered interventions and the observed during the survey cases of structural deficiencies (considered in detail in Chapter 4), vulnerability class A is assigned to these buildings. Vulnerability class B is assigned to the well-constructed masonry buildings and to the masonry buildings with reinforced concrete (RC) floors with construction deficiencies. Vulnerability class C is assigned to the well-constructed masonry buildings with reinforced concrete (RC) floors.

The European macroseismic scale (EMS), [1], distinguishes groups of RC structures without earthquake resistant design (ERD), with moderate level of ERD and with high level of ERD. In the affected area ERD for second category of seismicity has been required since 1974. The buildings were designed for peak ground acceleration of 0.07 g, [2]. According to the recent seismic macrozonation map, [3], an effective ground acceleration of 0.15 g is assigned to the affected area. Having in mind the relatively low magnitude of effective ground acceleration of 0.07 g, vulnerability class C is assigned to all RC structures. The quality of construction is not considered when attributing the vulnerability class of the RC buildings, since only one of them had slight non-structural damage and no special survey was performed.

Since the statistical data about the damage of the buildings were not completed at the time of the preparation of this report, the evaluation of the amount of the damaged buildings is based on expert estimation. 710 calls for survey of damaged buildings were received in Vobarno (including the associated fractions) and 426 in Sabbio Chiese (including the associated fractions) as of 1 of December 2004.

The European macroseismic scale and the Modified Mercalli scale are reported for the sake of convenience in Annex B.

3.2 Vobarno

The few negligibly damaged buildings were concentrated on the deposits along the river Chiese.

Very slight non-structural damage was observed in isolated buildings of class A and class B: hair-line cracks in plaster of the walls, as shown in Figures 3.1 and 3.2. A vertical crack in the masonry wall and fall of plaster was observed in one building, as illustrated in Figure 3.3. Having in mind the above observations **EMS intensity of V** and **Modified Mercalli intensity of 5** are assigned to the part of Vobarno located along the river.

Figure 3.1. Cracks in the plaster in a church in Vobarno

Figure 3.2. Cracks in the plaster of a Building in Vobarno

Figure 3.3. Vertical crack in the masonry wall and fall of plaster in Vobarno

3.3 Collio (fraction of Vobarno)

In Collio many of the masonry buildings of class A and few of class B suffered slight non-structural damage: hairline cracks in the walls, fall of small pieces of plaster, fall of loose bricks from the upper parts of the buildings (Figure 3.4). Few of the masonry buildings of class A suffered cracks in several walls (Figure 3.5) and in isolated cases cracking of walls of the structures of class B was observed (Figure 3.6). A failure of a wall of structure of class C, provoked by a non-engineered intervention was observed (Figure 4.17). In the RC buildings of class C the separation joints acted, as shown in Figure 3.7. On the basis of the above observations **EMS intensity of V/VI** and **Modified Mercalli intensity of 6** are assigned to Collio.

Figure 3.4. Fall of loose bricks in Collio

Figure 3.5. Cracks in the masonry walls

Figure 3.6. Failure of masonry wall

Figure 3.7. Separation joint in RC building

3.4 Pompegnino (fraction of Vobarno)

Considerable damage of the masonry structures was observed in Pompegnino: failure of masonry walls of poor quality (Figure 3.8), out-of-plane deformation and cracking of masonry walls (Figure 3.9), failure of masonry due to the lack of separation joints between buildings with different levels of the horizontal elements (Figure 3.10), separation of masonry walls from the RC slab, disintegration and failure of the unconfined masonry under the roof structures (Figure 3.11), cracking of windows piers. The upper part of the church bell tower suffered shear failure, it was cracked considerably due to pounding with an adjacent building, and the façade walls of the church were considerably cracked in the upper part.

Figure 3.8. Collapsed masonry wall

Figure 3.9. Out of plane deformation and cracking of a masonry wall

Figure 3.10. Lack of separation joint

Figure 3.11. Failure of the masonry under the roof

Isolated buildings of class A suffered damage of grade 3 (see Annex B), many buildings of class A and few buildings of class B and C suffered damage of grade 2, many buildings of class B suffered damage of grade 1, isolated buildings of class C (see figure 3.10) also exhibited damage of grade 2. As a result of the observations **EMS intensity of VI/VII** and **Modified Mercalli intensity of 7** are assigned to Pompegnino.

3.5 Pavone (fraction of Sàbbio Chiese)

The historical centre of Pavone as well as some relatively new buildings suffered considerable damage. There, diagonal cracks in the masonry walls were observed, together with failure of walls with poor quality (Figure 3.12), shear failure of masonry columns (Figure 3.13), out-of-plane deformation and cracking of slender masonry walls (Figure 3.14), disintegration and failure of the unconfined masonry under the roof structures (Figure 3.15). The external observation of the Pavone church has shown a slight structural damage.

Figure 3.12. Failure of masonry with poor quality

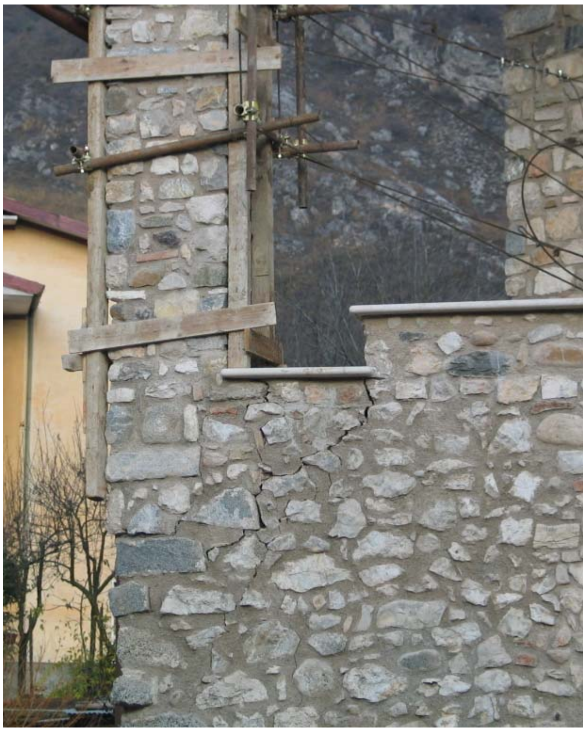


Figure 3.13. Shear failure of masonry

Figure 3.14. Failure of untied slender masonry wall

Figure 3.15. Failure of the masonry under the roof

Many masonry buildings of class A and few buildings of class B suffered damage of grade 2, most buildings of class A and many buildings of class B suffered damage of grade 1. Based on the above observations **EMS intensity of VI** and **Modified Mercalli intensity of 7** are assigned to Pompegnino.

3.6 Clibbio (fraction of Sàbbio Chiese)

In Clibbio masonry bilidings suffered considerable damage.

Figure 3.16. Pounding of adjacent buildings

Figure 3.17. Fallen 'coppi' tiles

Figure 3.18. Damages of the church

Figure 3.19. Partial separation of the façade walls

The survey has shown diagonal cracks in the masonry walls of many houses, failure of masonry due to the lack of separation joints between buildings with different levels of the horizontal elements (Figure 3.16), disintegration and failure of the unconfined masonry under the roof structures. In many houses the 'coppi' tiles have fallen from the roof

(Figure 3.17). The church was considerably damaged: the upper part of the bell tower suffered shear failure (Figure 3.18), the masonry was considerably cracked in many places due to interaction with adjacent structures (Figure 3.18), shear effects and out-of-plane bending. Partial separation of the façade walls was observed (Figure 3.19). Near Clibbio a rock-fall caused damages of the road (Figure 3.20).

The observation has shown that many masonry buildings of class A and few buildings of class B suffered damage of grade 2, most buildings of class A and many buildings of class B suffered damage of grade 1. Isolated buildings of class C suffered damage of grade 2. On this basis **EMS intensity of VI/VII** and **Modified Mercalli intensity of 7/8** are assigned to Clibbio.

Figure 3.20. Rock-fall near Clibbio

3.7 References

1. Conseil de l'Europe. *European macroseismic scale 1998 (EMS-98).* Cahier du Centre Européen de Géodynamique et de Séismologie, G. Gruenthal, editor. Luxemburg; 15, 1998.
2. D.M. Min. LLPP 16 Gennaio 1996, *"Norme Tecniche per le Costruzioni in Zone Sismiche"* (in Italian)
3. *Norme tecniche per il progetto, la valutazione e l'adeguamento sismico degli edifici*. Rome, 2003. (in Italian)

4 PERFORMANCE OF BUILDING STRUCTURES

4.1 Non-engineered masonry houses

The prevailing part of the residential building stock in the observed affected area consists of two or three story masonry houses, built before the last World War. The most severely damaged parts of the villages were the historical centers where the houses are 200-300 years old. During their long exploitation they were subjected to many reconstructions, which, together with the building techniques from the past and deterioration of the materials contributed their seismic vulnerability. As shown in Figure 4.1, the execution of a large opening in the massive contra-force wall contributed its failure. The infills of the larger openings separated and cracked, as shown in Figure 4.2. The new-built untied slender masonry wall in Pavone suffered out-of-plane-deformation and cracked, as shown in Figure 3.14.

Figure 4.1. House in Clibbio with a large opening in the bearing wall

Figure 4.2. Separation of infills in Collio

The weak connection of the roof structures with the unconfined masonry caused failure of the masonry (Figure 4.3) and, in some cases failure in the roof structure (Figure 4.4) due to the damaged supports.

Figure 4.3. Failure of the unconfined masonry under the roof in Pompegnino

Figure 4.4. Failure of the masonry support and of the roof in Clibbio

The weak connection of the floor and roof structures with the masonry as well as the insufficient in-plane stiffness of the floors and roofs did not allow the redistribution of the seismic forces between the individual walls. The walls separated along their joints and suffered out-of-plane deformation, as shown in Figure 4.5.

Figure 4.5. Separation of masonry walls in Pavone

Figure 4.6. Irregular structure in Clibbio

Another source of failure was the lack of separation joints between the houses. Adjacent structures with different height of the floors "bumped" against each other causing failure of the masonry in the neighbouring parts, as shown in Figure 4.16 for Collio. The irregular distribution of the stiffnesses and masses in-plan and along the height provoked failures in a house in Clibbio, as shown in Figure 4.6. The use of different materials for construction of the masonry walls caused their cracking and disintegration. In Figure 4.7 the failure of a masonry wall containing bricks and stones with different size is presented. The horizontal seismic loading caused sliding and failure of the 'coppi' tiles in many roofs in Clibbio and Pompegnino, as shown in Figure 3.17 and Figure 4.8.

Figure 4.7. Failure of masonry in Pavone

Figure 4.8. Sliding of 'coppi' tiles in Pompegnino

In Pavone, it was observed that old buildings that had even been retrofitted or partially rehabilitated shortly before the event suffered structural damage (Fig. 4.9-4.10). This damage can be explained by the fact that the rehabilitation interventions had mainly been targeted to non-structural members and had been designed without taking into proper account the seismic hazard.

Figure 4.9. Renovated house in Pavone

Figure 4.10. Renovated house in Pavone

The most heavily damaged parts of the churches in Pompegnino and Clibbio were the bell towers. In the two cases the masonry columns framing the upper part at the level of the bells are heavily sheared, as shown in Figure 4.11 for Clibbio and Figure 4.12 for Pompegnino. These heavy damages are caused by the improperly weak cross-sections of the masonry columns in comparison with the earthquake-induced inertial forces to the heavy bells, as well as by a torsional unbalance connected with the positioning of the bells with different masses.

Figure 4.11. The bell-tower in Clibbio

Figure 4.12.The bell-tower in Pompegnino

The slender façade walls of the two churches were cracked considerably in many places due to shear effects and out-of-plane bending (Figure 4.13 and Figure 4.14). The observed partial separation of the façade walls (Figure 3.19 and Figure 4.12) was most probably provoked by a weak connection between the walls and the roof.


Figure 4.13. The church in Clibbio


Figure 4.14. The church in Pompegnino

The vault of the church in Clibbio was cracked, as shown in Figure 4.15. The external observation of the church in Pavone has shown slight structural damage (Figure 4.16).


Figure 4.15. Cracks in the vault of the church in Clibbio


Figure 4.16. The church in Pavone

4.2 Engineered structures

4.2.1 Masonry structures with reinforced concrete slabs

Masonry structures with RC slabs suffered much less damage than non-engineered masonry structures.

Figure 4.17. Irregular structure in Pavone

The RC slabs tied together the masonry walls and redistributed the horizontal loading between them. The most common failures were cracking of the plaster and fall of small pieces of it. Nevertheless, in isolated cases, masonry structures with RC slabs suffered more substantial damage. In a house in Pavone, the lack of separation joint between the house and the associated structure created an irregular 'united' structure and, as a consequence the masonry in the second story of the house was damaged, as well as a stone masonry column of the penthouse failed in shear (Figure 4.17). The lack of separation joint between adjacent buildings caused failure of the masonry around the floors of the neighbouring building (Figure 4.18). Non-engineered interventions were also the cause of damage in the masonry structures with RC slabs. The failed thin masonry wall (Figure 4.19) observed in Collio most probably has been added to the structure during the reconstruction of the former garage in a room.

Figure 4.18. Pounding of adjacent buildings in Collio

Figure 4.19. Failed thin masonry wall in Collio

The quality of the masonry contributed substantially the damage of the walls. The poor quality of the workmanship caused the failure of the masonry wall shown in Figure 4.20. The hollow bricks with a small net cross-sectional area and insufficient thickness of the cross web and face shells used in some walls turned out to have much lower strength than the mortar (Figure 4.21).

Figure 4.20. Cracked masonry wall in Pompegnino

Figure 4.21. Hollow bricks used in Pompegnino

4.2.2 Reinforced concrete structures

No major damage was observed in RC structures. The separation joints acted in some buildings, as shown in Figure 3.7. A slight non-structural damage was observed only in an irregular RC building in Collio, where masonry walls separated from the RC frame. The irregularity was created by the absence of masonry walls in a considerable part of the first story in connection with its exploitation as a workshop (Figure 4.22). The absence of masonry walls in this part affected torsional unbalance and to a certain extent a 'soft first storey'. The resulted separations of the masonry walls in the second storey and in the first storey are shown in Figure 4.22 and Figure 4.23, respectively.

Figure 4.22. Irregular building in Collio

Figure 4.23. Separation of masonry walls

The lack of separation joints between RC buildings and older structures created pounding effects. The single-storey RC structure heavily damaged the adjacent masonry building in Pompegnino, as shown in Figure 4.24.

Figure 4.24. Pounding of adjacent structures in Pompegnino

4.3 Conclusion

The observation has shown that structures of good quality that had been properly designed for non-seismic conditions did not suffer structural damage. On the other hand, the earthquake caused significant damage to non-engineered masonry residential buildings and churches. The most severely damaged parts of the villages were the historical centres where the houses are 200-300 years old. The weak connection of the masonry walls with the roof and floor structures, the poor quality of workmanship and bricks, the lack of separation joints, the irregularities of the structures and the improper

reconstructions were the main sources of structural damage. The presence of ties in an important part of the existing masonry buildings prevented their partial collapse.
Finally, it was observed that even old buildings that had been retrofitted or partially rehabilitated shortly before the event suffered structural damage. This was due to the fact that the rehabilitation interventions had mainly been targeted to non-structural members and had been designed without taking into proper account the seismic hazard.

5 SOCIO-ECONOMIC EFFECTS AND EMERGENCY MANAGEMENT

5.1 General

The emergency situation in the Garda area was managed by a number of operators representing different governative or non-governative agencies and institutions, coordinated by Protezione Civile (Emergency Management Unit of the Italian Goverment), [1]. The centres where the field authority was concentrated were immediately established in some nevralgic small villages of the area. The main centre was the C.O.M. (the acronym for "Centro Operativo Misto", translation of Multi-tasking Operational Centre) arranged in Salò. As the name says, this kind of centre has the authority to operate in the emergency dealing with all possible kinds of problems. The Salò C.O.M. became active in the first hours after the event and was still operational at the time of the field mission (one week after the event). The main emergencies had all been dealt with, but no prevision on the date of dismantling of the Centre was anticipated.

The C.O.M., retaining the decisional power and the majority of contacts with the external institutions, was at first established in the Auditorium of the Secondary School of Salò and later moved to the Gymnasium of the same building, due to the need of more room to accommodate the different operative units. Other operative centres were established in the most severely stricken villages: they were named C.O.As, acronym for ("Centro Operativo Avanzato, meaning they were right on the spot where most of the damage and emergency intervention requests were concentrated). The C.O.A. that was visited during the field mission was located in Pompegnino, fraction of Vobarno.

The functions of the C.O.M.s and, subordinately, of the C.O.A.s are several:

- Assistance to Local Authorities
- Damage estimation
- Administrative support
- Transportation and road management
- Public safety
- Historical and cultural monuments preservation
- Information and public relations
- Urgent technical services and dangerous materials
- Scientific research and planning
- Public health
- Evacuation and logistics
- Volunteering coordination
- Telecommunications
- General secretariat

During the field mission contacts were taken with the Mayor of Vobarno, who was so kind as to personally give the ELSA team a picture of the damage distribution in his village and the relevant statistics for Vobarno, reported in the following. Moreover, he granted our team access to the fraction of Pompegnino, which had suffered the most significant damage, so that contact could be taken with Mr. Cadenelli from the local C.O.A., who led the team on a tour of the village to gather the photographic documentation reported above.

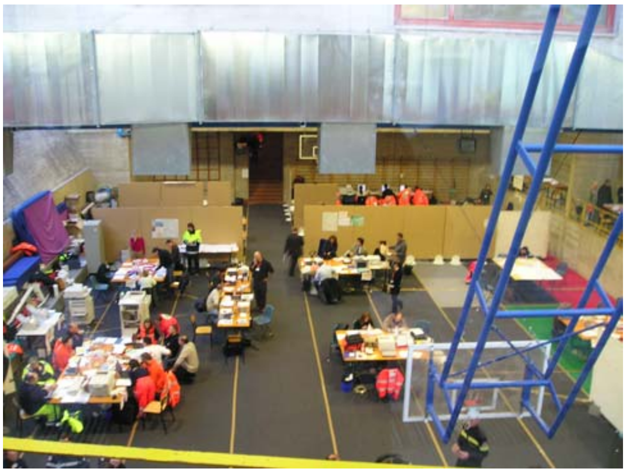


Figure 5.1. The Salò C.O.M.

Figure 5.2. Map of the requested and performed structural safety assessment interventions at the Salò C.O.M.

Figure 5.3. The Pompegnino C.O.A.

Figure 5.4. The Pompegnino camp kitchen and canteen

During the visit to the Salò C.O.M. contacts were taken with volunteers from Regione Lombardia, who were very helpful in providing us with the general statistics of the safety assessment interventions for the area, as reported in the following.

Moreover, contacts were taken with Professor Riva from the University of Brescia, who was also visiting the area with the task of estimating the safety of the building stock.

5.2 Statistics

5.2.1 Emergency operations

The emergency interventions in the area seemed appropriate, as for timing and efficiency. Starting from the very early hours after the event, Italian Protezione Civile took action: Vigili del Fuoco (Fire Brigade) and the Police were sent to the affected areas and damage emergency surveys were carried out. The C.O.M. was immediately set up in Salò. Regione Lombardia took charge of the management of the structural safety assessment interventions, carried out by qualified experts from the Municipalities and from the Lombardia Region together with Vigili del Fuoco. The Police (Forze dell'Ordine, which in Italy are represented by different corps, Carabinieri, Polizia di Stato and Guardia di Finanza) and the Italian Army, represented by the Alpini Corp, also had key roles in the initial phases of the emergency.

Moreover, according to the information received at the Salò C.O.M., a total of 300 volunteers were present, mainly from Lombardia, who provided useful and very effective help in all the operational tasks. The Italian Red Cross provided volunteers too.

As of the day of the visit, no official statistics were available regarding the emergency interventions and the damage survey and estimation. Anyhow, partial statistics were provided by the Salò C.O.M., about the intervention requests, performed safety verifications and certified damage in the 62 Municipalities involved in the emergency.

Table 5.1. Assisted population in the most damaged villages

Village	Pop.	Intervention Requests	Evacuated Pop.	Damage to public Buildings
Vobarno (Total)	7600	720	170	Primary School (Partial), Churches in Pompegnino and Carpeneda (Severe)
Sabbio Chiese	3172	426	125	Municipality (Partial) Primary School, Kindergarten (Severe)
Salò	10056	1612	330	Primary and Secondary School, Kindergarten (Partial), some roads closed
Villanuova sul Clisi	4776	345	29	Municipality (Severe), Primary School
Toscolano Maderno	7004	214	25	Some roads interrupted
Roe' Volciano	4174	500	127	All the Churches (Severe)
Total (62 Municipalities)	/	6070	1187	

In Tab. 5.1, the data for the most affected villages are reported; in the last row the total data for all the 62 Municipalities are given (the data on the population were taken from [2]).

In Annex A the official document for the request of intervention, that had to be filled in by the inhabitants of the damaged buildings, can be found.

5.2.2 Damage and economic losses

At present, no economic estimation of the damage has been carried out yet. At the time of the visit, Regione Lombardia and the Italian Government had allocated 10 million Euros each, for the emergency and urgent interventions. Further economic help to the affected Municipalities was foreseen as soon as reliable estimations of the needed interventions will be available.

A sample of the emergency safety interventions carried out on buildings at risk of partial failure are reported in Fig. 5.5-5.10.

Figure 5.5. Safety intervention on a stone masonry wall

Figure 5.6. Vigili del Fuoco intervening on the roof of a damaged building in Pompegnino

Figure 5.7. Vigili del Fuoco vehicles in Pompegnino

Figure 5.8. Vigili del Fuoco working on the roof of the heavily damaged church in Clibbio

Figure 5.9. Intervention on a severely damaged building in Pompegnino

Figure 5.10. Safety intervention in Collio

5.3 References

1. Protezione Civile, *http://www.protezionecivile.it/*
2. Comuni Italiani, *http://www.comuni-italiani.it*

6 CONCLUSIONS

The earthquake of 24 November 2004 was an event of average relevance, with no major features of intensity, damage caused or casualties.

The impact of the event was thus mainly confined at a local level. Damage of a certain extent developed only in older masonry structures, without engineered lateral load resistance and built with poor technology and bad quality workmanship.

Old constructions, such as 200- or 300-year-old houses or churches, suffered significant damage: this was probably the worst consequence of the earthquake, in terms of local heritage.

The warning that must be once again derived from such an event is on the seismic inadequacies of a relatively vast number of housing buildings, even in otherwise well-developed areas of Italy. The effects of good workmanship and structural detailing (such as the presence of ties) in avoiding major collapse even in relatively poor structures were also made clear; on the contrary, poor structural detailing and careless repair and/or change-of-use interventions turned out to be a major source of vulnerability, even for relatively good structures. Moreover, it was observed that even old buildings that had been retrofitted or partially rehabilitated shortly before the event suffered structural damage. This was due to the fact that the rehabilitation interventions had mainly been targeted to non-structural members and had been designed without taking into proper account the seismic hazard.

As for the impact on population, though, even if no casualties were originated by the event, the feeling of local authorities was that the importance of the consequences for a significant part of the local people was underrated or thoroughly neglected by the media which, to a certain extent, made it even more difficult for them to cope with the losses and the troubles.

This report is mainly intended to contributing towards a better understanding and documentation of the impact of the event from an engineering point of view, with the additional hope that, through this, a more objective and comprehensive picture of the local situation will be drawn.

ANNEX A

Post-earthquake damage evaluation forms, as provided by Italian Protezione Civile.

Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile
Ufficio Servizio Sismico Nazionale

GRUPPO NAZIONALE
DIFESA DAI TER

SCHEDA DI 1° LIVELLO DI RILEVAMENTO DANNO, PRONTO INTERVENTO E AGIBILITÀ PER EDIFICI ORDINARI NELL'EMERGENZA POST-SISMICA
(AeDES 05/2000)/bis   Codice Richiesta |_|_|_|_|_|_|_|_|

SEZIONE 1 Identificazione edificio

Provincia: ____________
Comune: ____________
Frazione/Località: ____________
(denominazione Istat)

Indirizzo
1 ○ via |_|_|_|_|_|_|_|_|_|_|_|_|_|
2 ○ corso
3 ○ vicolo |_|_|_|_|_|_|_|_|_|_|_|_|_|
4 ○ piazza   Num. Civico |_|_|_|_|
5 ○ altro ____________
(Indicare: contrada, località, traversa, salita, etc.)

IDENTIFICATIVO SOPRALLUOGO   giorno mese anno
Squadra |_|_|_| Scheda n.|_|_|_|_| Data |_|_|_|_|_|_|

IDENTIFICATIVO EDIFICIO
Istat Reg. | Istat Prov. | Istat Comune | N° aggregato | N° edifici
Cod. di Località Istat |_|_|_|_| Tipo carta
Sez. di censimento Istat |_|_|_| N° carta
Dati Catastali Foglio |_|_|_| Allegato |_|
Particelle |_|_|_|_|_|_|_|_|_|_|_|_|

Posizione edificio 1 ○ Isolato 2 ○ Interno 3 ○ D'estremità 4 ○ D'angol

Denominazione edificio o proprietario |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_| *Codice Uso* S |_|_|

Fotocopia dell'aggregato strutturale con identificazione dell'edificio

SEZIONE 2 Descrizione edificio

Dati metrici			Età	Uso - esposizione			
N° Piani totali con interrati	*Altezza media di piano* [m]	*Superficie media di piano* [m²]	*Costruzione e ristrutturaz.* [max 2]	*Uso*	*N° unità d'uso*	*Utilizzazione*	*Occupanti* (100 10 1)
○1 ○9	1 ○ ≤ 2.50	A ○ ≤ 50 / I ○ 400 ÷ 500	1 ☐ ≤ 1919	A ☐ Abitativo	|_|_|		
○2 ○10	2 ○ 2.50÷3.50	B ○ 50 ÷ 70 / L ○ 500 ÷ 650	2 ☐ 19 ÷ 45	B ☐ Produttivo	|_|_|	A ○ > 65%	0 0 0
○3 ○11	3 ○ 3.50÷5.0	C ○ 70 ÷ 100 / M ○ 650 ÷ 900	3 ☐ 46 ÷ 61	C ☐ Commercio	|_|_|	B ○ 30÷65%	1 1 1
○4 ○12	4 ○ > 5.0	D ○ 100 ÷ 130 / N ○ 900 ÷ 1200	4 ☐ 62 ÷ 71	D ☐ Uffici	|_|_|	C ○ < 30%	2 2 2
○5 ○>12		E ○ 130 ÷ 170 / O ○ 1200 ÷ 1600	5 ☐ 72 ÷ 81	E ☐ Serv. Pub.	|_|_|	D ○ Non utilizz.	3 3 3
○6	*Piani interrati*	F ○ 170 ÷ 230 / P ○ 1600 ÷ 2200	6 ☐ 82 ÷ 91	F ☐ Deposito	|_|_|	E ○ In costruz.	4 4 4 / 5 5 5
○7	A ○ 0 C ○ 2	G ○ 230 ÷ 300 / Q ○ 2200 ÷ 3000	7 ☐ 92 ÷ 01	G ☐ Strategico	|_|_|	F ○ Non finito	6 6 6 / 7 7 7
○8	B ○ 1 D ○ ≥3	H ○ 300 ÷ 400 / R ○ > 3000	8 ☐ ≥ 2002	H ☐ Turis-ricet.	|_|_|	G ○ Abbandon.	8 8 8 / 9 9 9

Proprietà A ○ Pubblica B ○ Privata

Istat Provincia |_|_|_| Istat Comune |_|_|_| Rilevatore |_|_| N° scheda |_|_|_|_|_| Data |_|_|_|_|_|_|

SEZIONE 3 Tipologia (multiscelta; per gli edifici in muratura indicare al massimo 2 tipi di combinazioni strutture verticali-solai)

Strutture verticali / Strutture orizzontali	Non identificate	Strutture in muratura: A tessitura irregolare e di cattiva qualità (Pietrame non squadrato, ciottoli,..) – Senza catene o cordoli	A tessitura irregolare e di cattiva qualità – Con catene o cordoli	A tessitura regolare e di buona qualità (Blocchi; mattoni; pietra squadrata,..) – Senza catene o cordoli	A tessitura regolare e di buona qualità – Con catene o cordoli	Pilastri isolati	Mista	Rinforzata
	A	B	C	D	E	F	G	H
1 Non identificate	○	☐	☐	☐	☐	SI	☐	☐
2 Volte senza catene	☐	☐	☐	☐	☐	○	G1	H1
3 Volte con catene	☐	☐	☐	☐	☐		☐	☐
4 Travi con soletta **deformabile** (travi in legno con semplice tavolato, travi e voltine,...)	☐	☐	☐	☐	☐	NO	G2	H2
5 Travi con soletta **semirigida** (travi in legno con doppio tavolato, travi e tavelloni,...)	☐	☐	☐	☐	☐	○	☐	☐
6 Travi con soletta **rigida** (solai di c.a., travi ben collegate a solette di c.a.,...)	☐	☐	☐	☐	☐		G3	H3

Altre strutture	
Telai in c.a.	☐
Pareti in c. a.	☐
Telai in acciaio	☐

REGOLARITA'	Non regolare	Regolare
	A	B
1 Forma pianta ed elevazione	○	○
2 Disposizione tamponature	○	○

Copertura

1 ○ Spingente pesante
2 ○ Non spingente pesante
3 ○ Spingente leggera
4 ○ Non spingente leggera

SEZIONE 4 Danni ad ELEMENTI STRUTTURALI e provvedimenti di pronto intervento (P.I.) eseguiti

Livello - estensione / Componente strutturale - Danno preesistente	DANNO [1] D4-D5 Gravissimo > 2/3	D4-D5 1/3 - 2/3	D4-D5 < 1/3	D2-D3 Medio grave > 2/3	D2-D3 1/3 - 2/3	D2-D3 < 1/3	D1 Leggero > 2/3	D1 1/3 - 2/3	D1 < 1/3	Nullo	PROVEDIMENTI DI P.I. ESEGUITI: Nessuno	Demolizioni	Cerchiature e/o tiranti	Riparazione	Puntelli	Transenne e protezione passaggi
	A	B	C	D	E	F	G	H	I	L	A	B	C	D	E	F
1 Strutture verticali	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
2 Solai	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
3 Scale	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
4 Copertura	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
5 Tamponature-tramezzi	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐		☐	☐	☐
6 Danno preesistente	☐	☐	☐	☐	☐	☐	☐	☐	☐	○						

(1) - Di ogni livello di danno indicare l'estensione solo se esso è presente. Se l'oggetto indicato nella riga non è danneggiato campire **Nullo.**

SEZIONE 5 Danni ad ELEMENTI NON STRUTTURALI e provvedimenti di pronto intervento eseguiti

Tipo di danno	PRESENZA DANNO	PROVVEDIMENTI DI P.I. ESEGUITI: Nessuno	Rimozione	Puntelli	Riparazione	Divieto di accesso	Transenne e protezione passaggi
	A	B	C	D	E	F	G
1 Distacco intonaci, rivestimenti, controsoffitti...	○	○	☐	☐	☐	☐	☐
2 Caduta tegole, comignoli...	○	○	☐	☐	☐	☐	☐
3 Caduta cornicioni, parapetti...	○	○	☐	☐	☐	☐	☐
4 Caduta altri oggetti interni o esterni	○	○	☐	☐	☐	☐	☐
5 Danno alla rete idrica, fognaria o termoidraulica	○	○			☐	☐	☐
6 Danno alla rete elettrica o del gas	○	○			☐	☐	☐

SEZIONE 6 Pericolo ESTERNO indotto da altre costruzioni e provvedimenti di p.i. eseguiti

Causa potenziale	PERICOLO SU: Edificio	Via d'accesso	Vie interne	PROVVEDIM. DI P.I. ESEGUITI: Divieto di accesso	Transenne e protez. passaggi
	A	B	C	D	E
1 Crolli o cadute da altre costruzioni	☐	☐	☐	☐	☐
2 Rottura di reti di distribuzione	☐	☐	☐	☐	☐

SEZIONE 7 Terreno e fondazioni

MORFOLOGIA DEL SITO	DISSESTI (in atto o temibili): ☐ Versanti incombenti ☐ Terreno di fondazione
1 ○ Cresta 2 ○ Pendio forte 3 ○ Pendio leggero 4 ○ Pianura	A ○ Assenti B ○ Generati dal sisma C ○ Acuiti dal sisma D ○ Preesistenti

Istat Provincia |__|__|__| Istat Comune |__|__|__| Rilevatore |__|__| N° scheda |__|__|__|__|__|Data |__|__|__|__|__|__|

SEZIONE 8 Giudizio di agibilità

Valutazione del rischio

RISCHIO	STRUTTURALE (Sezz. 3 e 4)	NON STRUTTURALE (Sez. 5)	ESTERNO (sez. 6)	GEOTECNICO (sez. 7)
BASSO	○	○	○	○
BASSO CON PROVVEDIMENTI	○	○	○	○
ALTO	○	○	○	○

Esito di agibilità

A	Edifico AGIBILE	○
B	Edificio TEMPORANEAMENTE INAGIBILE (tutto o parte) ma AGIBILE con provvedimenti di pronto intervento (1)	○
C	Edificio PARZIALMENTE INAGIBILE (1)	⌀
D	Edificio TEMPORANEAMENTE INAGIBILE da rivedere con approfondimento	○
E	Edificio INAGIBILE	○
F	Edificio INAGIBILE per rischio esterno (1)	○

(1) riportare nella colonna argomento della Sez. 9 l'esito e nelle annotazioni le parti di edificio inagibili (esiti B, C) e le cause di rischio esterno (esito F)

Sull'accuratezza della visita: 1 ○ Solo dall'esterno 2 ○ Parziale 3 ○ Completa (> 2/3) 4 ○ Non eseguito per: a ○ Sopralluogo rifiutato (SR) b ○ Rudere (RU) c ○ Demolito (DM) d ○ Proprietario non trovato (NT) e ○ Altro (AL) ....

Provvedimenti di pronto intervento di rapida realizzazione, limitati (*) o estesi (**)

	*	**	PROVVEDIMENTI DI P.I. SUGGERITI		*	**	PROVVEDIMENTI DI P.I. SUGGERITI
1	☐	☐	Messa in opera di cerchiature o tiranti	7	☐	☐	Rimozione di cornicioni, parapetti, aggetti
2	☐	☐	Riparazione danni leggeri alle tamponature e tramezzi	8	☐	☐	Rimozione di altri oggetti interni o esterni
3	☐	☐	Riparazione copertura	9	☐	☐	Transennature e protezione passaggi
4	☐	☐	Puntellatura di scale	10	☐	☐	Riparazioni delle reti degli impianti
5	☐	☐	Rimozione di intonaci, rivestimenti, controsoffittature	11	☐	☐	
6	☐	☐	Rimozione di tegole, comignoli, parapetti	12	☐	☐	

Unità immobiliari inagibili, famiglie e persone evacuate

Unità immobiliari inagibili |__|__| Nuclei familiari evacuati |__|__| N° persone evacuate |__|__|__|

SEZIONE 9 Altre osservazioni

Sul danno, sui provvedimenti di pronto intervento, l'agibilità o altro

Argomento	*Annotazioni*
	Foto d'insieme dell'edificio — spilla

Il compilatore (in stampatello)	*Firma*

NOTE ESPLICATIVE SULLA COMPILAZIONE DELLA SCHEDA AeDES 05/2000/bis

La scheda va compilata per un intero edificio intendendo per edificio una unità strutturale "cielo terra", individuabile per caratteristiche tipologiche e quindi distinguibile dagli edifici adiacenti per tali caratteristiche e anche per differenza di altezza e/o età di costruzione e/o piani sfalsati, etc.

La scheda è divisa in 9 **sezioni**. Le informazioni sono generalmente definite annerendo le caselle corrispondenti; in alcune sezioni la presenza di caselle quadrate (☐) indicano la possibilità di multiscelta: in questi casi si possono fornire più indicazioni; le caselle tonde (○) indicano la possibilità di una singola scelta. Dove sono presenti le caselle |__| si deve scrivere in stampatello appoggiando il testo a sinistra ed i numeri a destra.

Sezione 1 - Identificazione edificio.
Indicare i dati di localizzazione: Provincia, Comune e Frazione.
IDENTIFICATIVO SCHEDA: Il rilevatore riporta il proprio numero assegnato dal coordinamento centrale, un numero progressivo di scheda e la data del sopralluogo.
IDENTIFICATIVO EDIFICIO
L'organizzazione del rilevamento prevede un Coordinamento Tecnico e la collaborazione dell'ufficio tecnico comunale. Questo ha tra l'altro il compito di assistenza per l'espletamento del lavoro dei rilevatori e per l'individuazione degli edifici. L'edificio in generale non è pre-individuato ed è quindi compito del rilevatore il suo riconoscimento e la sua identificazione sulla cartografia riportata nello spazio della prima facciata. Il codice identificativo dell'edificio, costituito dall'insieme dei dati della prima riga nello spazio in grigio, viene poi assegnato, in modo univoco, presso il coordinamento comunale dove i rilevatori, dopo la visita comunicano l'esito del sopralluogo. La numerazione degli aggregati e degli edifici deve essere tenuta aggiornata in una cartografia generale presso il coordinamento comunale in modo che i rilevatori possano riferire le visite di sopralluogo, che sono richieste in genere su unità immobiliari, all'edificio che effettivamente le contiene. Per l'identificativo, il n° di carta, i dati Istat e i dati catastali è necessario quindi avvalersi della collaborazione del coordinamento comunale. Posizione edificio: se l'edificio non è isolato su tutti i lati, va indicata la sua posizione all'interno dell'aggregato (Interno, d'estremità, angolo). Denominazione edificio o proprietario: indicare la denominazione se edificio pubblico o il nome del condominio o di uno dei proprietari se privato (es. : Condominio Verde, Rossi Mario).

Sezione 2 - Descrizione edificio
N° piani totali con interrati: indicare il numero di piani complessivi dell'edificio dallo spiccato di fondazioni incluso quello di sottotetto solo se praticabile. Computare interrati i piani mediamente interrati per più di metà della loro altezza. Altezza media di piano: indicare l'altezza che meglio approssima la media delle altezze di piano presenti. Superficie media di piano: va indicato l'intervallo che comprende la media delle superfici di tutti i piani. Età (2 opzioni): è possibile fornire 2 indicazioni: la prima è sempre l'età di costruzione, a seconda è l'eventuale anno in cui si sono effettuati eventuali nterventi *sulle strutture*. Uso (multiscelta): indicare i tipi di uso compresenti nell'edificio. Utilizzazione: l'indicazione abbandonato si iferisce al caso di *non utilizzato in cattive condizioni*.

Sezione 3 - Tipologia (massimo 2 opzioni)
Per gli edifici in muratura si possono segnalare le due combinazioni: trutture orizzontali e verticali prevalenti o più vulnerabili; ad sempio: volte senza catene e muratura in pietrame al 1° livello (2B) solai rigidi (in c.a.) e muratura in pietrame al 2° livello (6B). La uratura è distinta in due tipi in ragione della qualità (materiali, gante, realizzazione) e per ognuno è possibile segnalare anche la esenza di cordoli o catene se sono sufficientemente diffusi; è nche da rilevare l'eventuale presenza di pilastri isolati, siano essi in a., muratura, acciaio o legno e/o la presenza di situazioni miste di uratura e strutture intelaiate. Gli edifici si considerano con strutture elaiate di c.a. o d'acciaio, se l'intera struttura portante è in c.a. o in ciaio. Situazioni miste (muratura-telai) o rinforzi vanno indicate, n modalità multiscelta, nelle colonne G ed H della parte uratura".

: c.a. (o altre strutture intelaiate) su muratura
: muratura su c.a. (o altre strutture intelaiate)
: Muratura mista a c.a. (o altre strutture intelaiate) in parallelo sugli stessi piani

H1: Muratura rinforzata con iniezioni o intonaci non armati
H2: Muratura armata o con intonaci armati
H3: Muratura con altri o non identificati rinforzi

Per le strutture intelaiate le tamponature sono irregolari qu presentano dissimmetrie in pianta e/o in elevazione o sor pratica completamente assenti in un piano in almeno una direzio

Sezione 4 - Danni ad ELEMENTI STRUTTURALI PRINCIPALI
I danni da riportare nella sezione 4 sono quelli 'apparenti', quelli riscontrabili a vista. Nella tabella ogni riga è riferita ad ur di componente l'organismo strutturale, mentre le colonne differenziate in modo da consentire di rilevare i livelli di d. presenti sulla componente e le relative estensioni in percen rispetto alla sua totalità nell'edificio.
La definizione del livello di danno riscontrato è di partico rilevanza, essa è basata sulla scala macrosismica europea EM: integrata con le definizioni puntuali utilizzate nelle schede di ril GNDT. In particolare si farà riferimento alla sommaria descrizi riportata di seguito, maggiori dettagli sono riportati nel manuale:
D1 danno leggero è un danno che non cambia in m significativo la resistenza della struttura e non pregiudica sicurezza degli occupanti a causa di cadute di elementi strutturali; il danno è leggero anche se queste ultime poss rapidamente essere scongiurate.
D2-D3 danno medio – grave: è un danno che potrebbe anc cambiare in modo significativo la resistenza della struttura ser che venga avvicinato palesemente il limite del crollo parziale elementi strutturali principali.
D4-D5 danno gravissimo: è un danno che modifica in mo evidente la resistenza della struttura portandola vicino al limite c crollo parziale o totale di elementi strutturali principali. Sta descritto da danni superiori ai precedenti, incluso il collasso.

Provvedimenti di pronto intervento eseguiti: sono quelli che co tempi e mezzi limitati conseguono una eliminazione o riduzion accettabile del rischio; vanno indicati quelli già messi in atto.

Sezione 5 - Danni ad ELEMENTI NON STRUTTURALI...
Per gli elementi non strutturali va indicata la presenza del danno e gl eventuali provvedimenti già in atto, con modalità multiscelta.

Sezione 6 - Pericolo ESTERNO ed interventi di (p.i.) eseguiti
Indicare i pericoli indotti da costruzioni adiacenti e/o dal contesto e gl eventuali provvedimenti presi, con modalità multiscelta.

Sezione 7 - Terreno e fondazioni
Va individuata la morfologia del sito ed eventuali dissesti sul terreno e/o sulla fondazione, in atto o temibili.

Sezione 8 - Giudizio di AGIBILITÀ
Il rilevatore stabilisce le condizioni di rischio dell'edificio (tabella *valutazione del rischio*) sulla base delle informazioni raccolte dell'ispezione visiva e delle proprie valutazioni, relativamente alle condizioni strutturali (Sezione 3 e 4 - Tipologia e danno), alle condizioni degli elementi non strutturali (Sezione 5), al pericolo derivante dalle altre costruzioni (Sezione 6) e alla situazione geotecnica (Sezione 7); . L'esito B va indicato quando la riduzione del rischio si può conseguire con il *pronto intervento (opere d consistenza limitata, di rapida e facile esecuzione che rendono agibile l'edificio)*. L'esito D solo in casi particolarmente problematici e soprattutto se si tratta di edifici pubblici la cui inagibilità compromette funzioni importanti.
Unità immobiliari inagibili, famiglie e persone evacuate: sono d indicare gli effetti del giudizio di inagibilità, qualora confermato da Sindaco; vanno pertanto indicate anche le famiglie e persone d evacuare, oltre a quelle che abbiano già lasciato l'edificio.
Provvedimenti di pronto intervento: indicare i provvediment necessari per rendere agibile l'edificio e/o per eliminare rischi indotti.

Sezione 9 - Altre osservazioni
Accuratezza della visita: indicare con quale livello di accuratezza e completezza è stato possibile effettuare il sopralluogo .
Sul danno, sui provvedimenti di pronto intervento, l'agibilità o altro: riportare le annotazioni che si ritengono importanti per meglio precisare i vari aspetti del rilevamento. L'eventuale fotografia d'insieme dell'edificio deve essere spillata nel riquadro tratteggiato in chiaro e nel solo angolo in alto a destra.

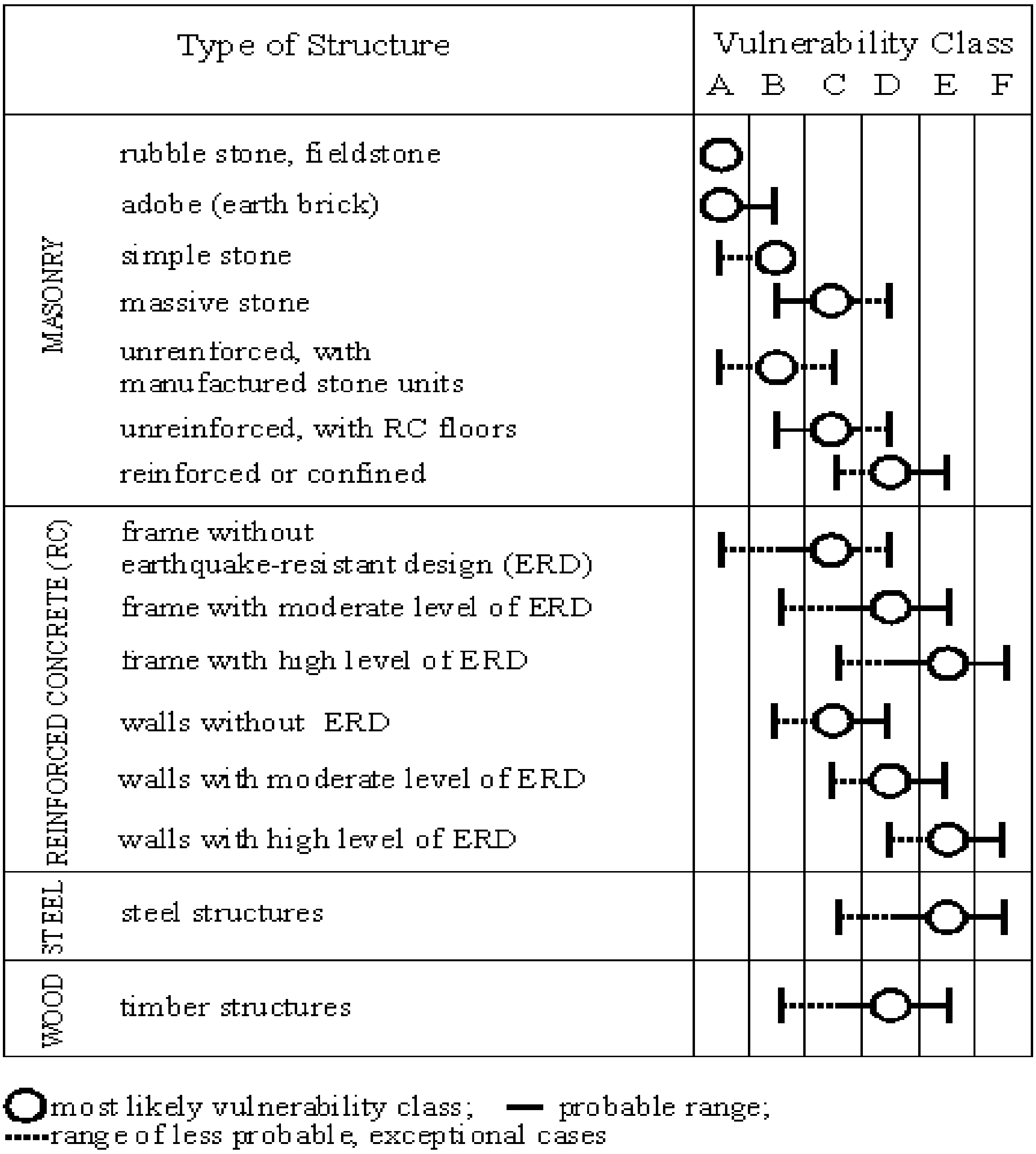
ANNEX B

EUROPEAN MACROSEISMIC INTENSITY SCALE

Classifications used in the European Macroseismic Scale (EMS)

Differentiation of structures (buildings) into vulnerability classes

(Vulnerability Table)

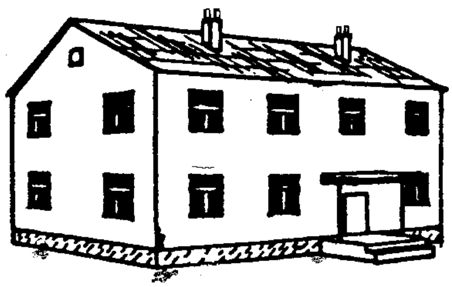
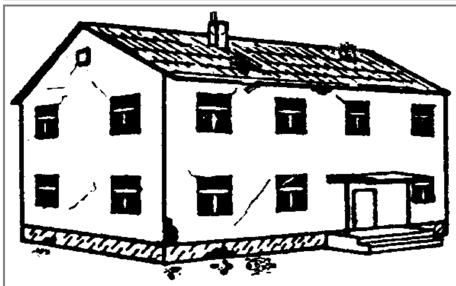
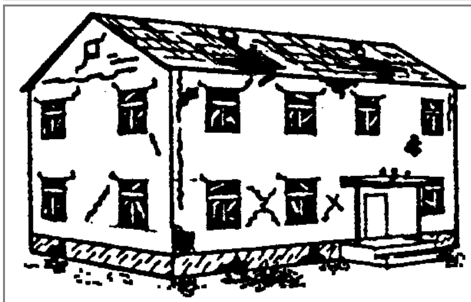


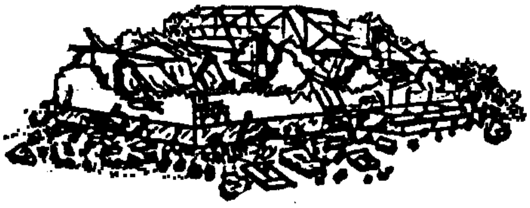
The masonry types of structures are to be read as, e.g., simple stone masonry, whereas the reinforced concrete (RC) structure types are to be read as, e.g., RC frame or RC wall.

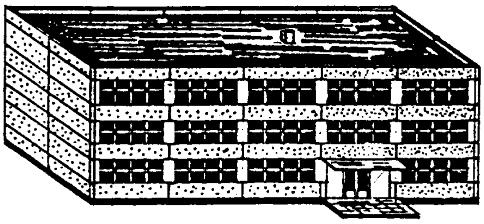
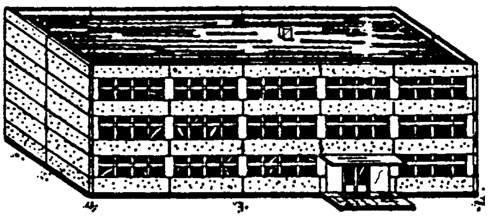
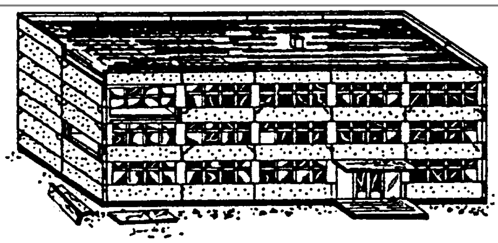
See section 2 of the Guidelines and Background Materials for more details, also with respect to the use of structures with earthquake resistant design.

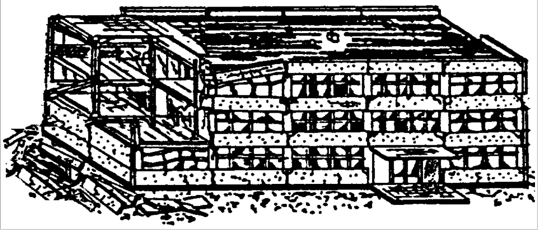
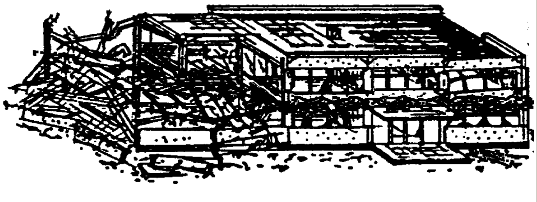
Classification of damage

Note: the way in which a building deforms under earthquake loading depends on the building type. As a broad categorisation one can group together types of masonry buildings as well as buildings of reinforced concrete.

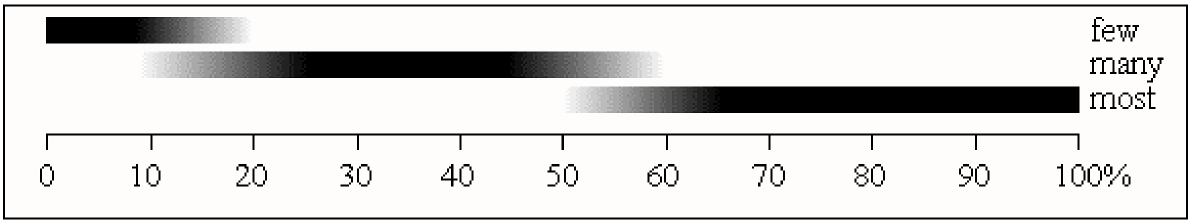
Classification of damage to masonry buildings	
	**Grade 1: Negligible to slight damage** **(no structural damage,** **slight non-structural damage)** Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
	**Grade 2: Moderate damage** **(slight structural damage, moderate** **non-structural damage)** Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys.
	**Grade 3: Substantial to heavy damage** **(moderate structural damage,** **heavy non-structural damage)** Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
	**Grade 4: Very heavy damage** **(heavy structural damage,** **very heavy non-structural damage)** Serious failure of walls; partial structural failure of roofs and floors.

	**Grade 5: Destruction** **(very heavy structural damage)** Total or near total collapse.

Classification of damage to buildings of reinforced concrete	
	**Grade 1: Negligible to slight damage** **(no structural damage,** **slight non-structural damage)** Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and infills.
	**Grade 2: Moderate damage** **(slight structural damage,** **moderate non-structural damage)** Cracks in columns and beams of frames and in structural walls. Cracks in partition and infill walls; fall of brittle cladding and plaster. Falling mortar from the joints of wall panels.
	**Grade 3: Substantial to heavy damage** **(moderate structural damage,** **heavy non-structural damage)** Cracks in columns and beam column joints of frames at the base and at joints of coupled walls. Spalling of conrete cover, buckling of reinforced rods. Large cracks in partition and infill walls, failure of individual infill panels.
	Grade 4: Very heavy damage **(heavy structural damage,** **very heavy non-structural damage)** Large cracks in structural elements with

	compression failure of concrete and fracture of rebars; bond failure of beam reinforced bars; tilting of columns. Collapse of a few columns or of a single upper floor.
	**Grade 5: Destruction** **(very heavy structural damage)** Collapse of ground floor or parts (e. g. wings) of buildings.

Definitions of quantity



Definitions of intensity degrees

Arrangement of the scale:

a) Effects on humans

b) Effects on objects and on nature

(effects on ground and ground failure are dealt with especially in Section 7)

c) Damage to buildings

Introductory remark:

The single intensity degrees can include the effects of shaking of the respective lower intensity degree(s) also, when these effects are not mentioned explicitly.

I. Not felt

a) Not felt, even under the most favourable circumstances.

b) No effect.

c) No damage.

II. Scarcely felt

a) The tremor is felt only at isolated instances (<1%) of individuals at rest and in

a specially receptive position indoors.

b) No effect.

c) No damage.

III. Weak

a) The earthquake is felt indoors by a few. People at rest feel a swaying or light trembling.

b) Hanging objects swing slightly.

c) No damage.

IV. Largely observed

a) The earthquake is felt indoors by many and felt outdoors only by very few. A few people are awakened. The level of vibration is not frightening. The vibration is moderate. Observers feel a slight trembling or swaying of the building, room or bed, chair etc.

b) China, glasses, windows and doors rattle. Hanging objects swing. Light furniture shakes visibly in a few cases. Woodwork creaks in a few cases.

c) No damage.

V. Strong

a) The earthquake is felt indoors by most, outdoors by few. A few people are frightened and run outdoors. Many sleeping people awake. Observers feel a strong shaking or rocking of the whole building, room or furniture.

b) Hanging objects swing considerably. China and glasses clatter together. Small, top-heavy and/or precariously supported objects may be shifted or fall down. Doors and windows swing open or shut. In a few cases window panes break. Liquids oscillate and may spill from well-filled containers. Animals indoors may become uneasy.

c) Damage of grade 1 to a few buildings of vulnerability class A and B.

VI. Slightly damaging

a) Felt by most indoors and by many outdoors. A few persons lose their balance. Many people are frightened and run outdoors.

b) Small objects of ordinary stability may fall and furniture may be shifted. In few instances dishes and glassware may break. Farm animals (even outdoors) may be frightened.

c) Damage of grade 1 is sustained by many buildings of vulnerability class A and B; a few of class A and B suffer damage of grade 2; a few of class C suffer damage of grade 1.

VII. Damaging

a) Most people are frightened and try to run outdoors. Many find it difficult to stand, especially on upper floors.

b) Furniture is shifted and top-heavy furniture may be overturned. Objects fall from shelves in large numbers. Water splashes from containers, tanks and pools.

c) Many buildings of vulnerability class A suffer damage of grade 3; a few of grade 4.

Many buildings of vulnerability class B suffer damage of grade 2; a few of grade 3.

A few buildings of vulnerability class C sustain damage of grade 2.

A few buildings of vulnerability class D sustain damage of grade 1.

VIII. Heavily damaging

a) Many people find it difficult to stand, even outdoors.

b) Furniture may be overturned. Objects like TV sets, typewriters etc. fall to the ground. Tombstones may occasionally be displaced, twisted or overturned. Waves may be seen on very soft ground.

c) Many buildings of vulnerability class A suffer damage of grade 4; a few of grade 5.

Many buildings of vulnerability class B suffer damage of grade 3; a few of grade 4.

Many buildings of vulnerability class C suffer damage of grade 2; a few of grade 3.

A few buildings of vulnerability class D sustain damage of grade 2.

IX. Destructive

a) General panic. People may be forcibly thrown to the ground.

b) Many monuments and columns fall or are twisted. Waves are seen on soft ground.

c) Many buildings of vulnerability class A sustain damage of grade 5.

Many buildings of vulnerability class B suffer damage of grade 4; a few of grade 5.

Many buildings of vulnerability class C suffer damage of grade 3; a few of grade 4.

Many buildings of vulnerability class D suffer damage of grade 2; a few of grade 3.

A few buildings of vulnerability class E sustain damage of grade 2.

X. Very destructive

c) Most buildings of vulnerability class A sustain damage of grade 5.

Many buildings of vulnerability class B sustain damage of grade 5.

Many buildings of vulnerability class C suffer damage of grade 4; a few of grade 5.

Many buildings of vulnerability class D suffer damage of grade 3; a few of grade 4.

Many buildings of vulnerability class E suffer damage of grade 2; a few of grade 3.

A few buildings of vulnerability class F sustain damage of grade 2.

XI. Devastating

c) Most buildings of vulnerability class B sustain damage of grade 5.

Most buildings of vulnerability class C suffer damage of grade 4; many of grade 5.

Many buildings of vulnerability class D suffer damage of grade 4; a few of grade 5.

Many buildings of vulnerability class E suffer damage of grade 3; a few of grade 4.

Many buildings of vulnerability class F suffer damage of grade 2; a few of grade 3.

XII. Completely devastating

c) All buildings of vulnerability class A, B and practically all of vulnerability class C are destroyed. Most buildings of vulnerability class D, E and F are destroyed. The earthquake effects have reached the maximum conceivable effects.

Modified Mercalli Scale

Average peak velocity (centimeters per second)	**Intensity value and description**	**Average peak acceleration (g is gravity=9.80 meters per second squared)**
	I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel scale)	
	II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale)	
	III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale)	
1-2	**IV.** During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing automobiles rocked noticeably. (IV to V Rossi-Forel scale)	0.015g-0.02g
2-5	**V.** Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale)	0.03g-0.04g
5-8	**VI.** Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale)	0.06g-0.07g
8-12	**VII.** Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys	0.10g-0.15g

	broken. Noticed by persons driving cars. (VIII Rossi-Forel scale)	
20-30	**VIII.** Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stack, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. (VIII + to IX Rossi-Forel scale)	0.25g-0.30g
45-55	**IX.** Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX + Rossi-Forel scale)	0.50g-0.55g
More than 60	**X.** Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks. (X Rossi-Forel scale)	More than 0.60g
	XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.	
	XII. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.	

Bolt, Bruce A. Abridged Modified Mercalli Intensity Scale, *Earthquakes - Newly Revised and Expanded*, Appendix C, W.H. Freeman and Co. 1993, 331 pp.